

SECTION 1

NATURAL DISASTER REDUCTION --Reducing the Impacts of Natural Hazards

INTRODUCTION

The United Nations declared the 1990's to be the International Decade for Natural Disaster Reduction (IDNDR). The IDNDR is based on the premise that so-called natural disasters are primarily social in origin. While natural hazards, like earthquakes, storms, floods, drought, and other geophysical extremes are inevitable, disasters reflect societies' ways of doing business. They result from decisions and policies on land use, engineering practice, ecosystem management, and social institutions and frameworks. As a result, disasters evolve rapidly in response to great societal change--population increase, economic growth, the globalization of commerce, technological advances, and other trends now underway worldwide.

The United States estimate for natural disaster-related economic losses is approximately \$1 billion per week. While this estimate appears to be high, it is only two-thirds of 1 percent of the United States' gross domestic product



Figure 1-1. Hurricane Mitch approaching Honduras on October 26, 1998 at 13:15 UTC
(Source: NASA/GSFC)

DISASTERS--
disruptions of entire communities, persisting after the hazard has come and gone, and exceeding the communities' ability to recover unaided.

(GDP). By contrast, the Chinese loss from flooding in 1998 is in the range of 5-7 percent of GDP. For smaller nations, such as those in the Caribbean and Central America, a single event, e.g., Hurricane Mitch (Figure 1-1), can produce losses comparable to 50 percent of GDP. The threat is not confined only to developing nations. Estimates suggest that a repeat of the Great Kanto earthquake (1923) would today cost Japan well over one trillion dollars--a significant fraction of its total economy. Munich Reinsurance figures show a doubling or tripling of economic losses worldwide over each of the last several decades. Their estimates suggest that losses for 1995, which included the Kobe earthquake, approached \$180 billion, and 1998 was the most costly year ever for weather-related disasters, with losses from this source alone approaching \$90 billion. The United States' loss experience reflects similar global trends. For hurricane damage alone, costs seem to be rising almost exponentially (Figure 1-2).

Although the United States was already addressing the effects of natural disasters, the IDNDR program helped focus the need for a coordinated natural disaster reduction program. The National Science and Technology Council's Committee on the

Environment and Natural Resources formed the Subcommittee for Natural Disaster Reduction (SNDR) which brought together 19 federal agencies with the goal to initiate interagency coordination of research efforts to address natural disaster reduction needs. In December 1996, SNDR published *Natural Disaster Reduction: A Plan for the Nation* to highlight ongoing federal research efforts in this science and technology field and to identify new and promising areas where there might be gaps in federal support.

Early on, coordinated international efforts were focused on three targets:

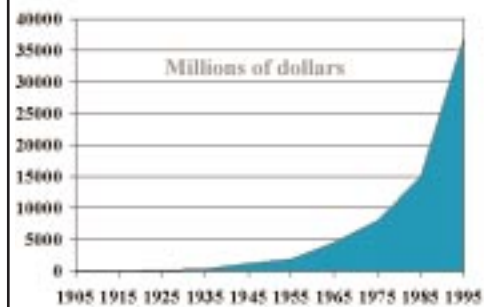


Figure 1-2. United States Hurricane damage by decades.

identify hazards, assess risk, and promote research; develop and implement mitigation plans; and implement regional warning and dissemination systems. Over the past decade, the United States has made significant progress with respect to the first two targets and substantially improved regional warning and dissemination systems. The following paragraphs contain examples for all three targets.

IDENTIFY HAZARDS, ASSESS RISK, AND PROMOTE RESEARCH

Hazard identification and risk assessment are the essential first steps. In a

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specific application, the Federal Emergency Management Agency (FEMA), in partnership with the National Institute for Building Sciences has developed HAZard US (HAZUS) a geographic information system (GIS)-based computer program to estimate earthquake losses. HAZUS incorporates classification systems for buildings. The methodology is already being used in the San Francisco Bay and greater New York City areas. FEMA is currently generalizing the software to incorporate hydrometeorological hazards and is training state and local officials to use HAZUS.

More than 100 experts from many institutions and disciplines, under the leadership of the Natural Hazard Research and Applications Information Center (NHRAIC), have worked for more than 5 years to conduct a Second Research Assessment. (This supersedes the First Research Assessment, carried out more than two decades ago). The assessment attempts to pull together, in one summary document, what is known about the evolving nature and causes of natural disasters. During late spring 1999, they published a summary of their findings. The overall assessment is that, by and large, most of the roots of natural disasters are not geophysical or even engineering, but rather societal in origin. Furthermore, decisions with respect to natural disaster reduction cannot be made in isolation but must be made in a larger context of sustainable development and other societal goals.

DEVELOP AND IMPLEMENT MITIGATION PLANS

During the past decade, the United States, with FEMA leadership, has made a shift in policy emphasis from reliance on emergency response and reconstruction alone to increasing pre-event efforts to mitigate the impacts of natural hazards. With state and local emergency managers, FEMA developed a National Mitigation Strategy

and implemented Project Impact. The goal of Project Impact is to "help communities protect themselves from the devastating effects of natural disasters by taking actions that dramatically reduce disruption and loss."

Through a relatively small direct investment, FEMA has leveraged other federal efforts and achieved a remarkable catalytic effect in local/private-sector action. Many other communities are beginning to take corresponding actions, even without federal funding. As a result, the United States is well on the way to developing a significant, sustained national mitigation effort that should continue well into the 21st Century. Detailed information on Project Impact can be found on FEMA's web site at www.fema.gov.

IMPLEMENT REGIONAL WARNING AND DISSEMINATION SYSTEMS

Throughout the 1990's, federal agencies, both independently and in coordinated programs, have taken steps to provide extraordinary improvement in their ability to forecast and warn of coming hazards. Examples include:

- volcanic activity--United States Geological Survey (USGS) provides public notices of escalating risk for volcanic activity and has developed a color-coded risk assessment based on the level of activity. The Federal Aviation Administration (FAA), National Oceanic and Atmospheric Administration (NOAA), USGS, and National Aeronautics and Space Administration (NASA) have instituted an operational capability to alert aircraft of the presence of volcanic ash plumes. Geostationary and polar-orbiting satellites observe plumes injected into the atmosphere by volcanic explosions, and nine worldwide volcanic ash advisory centers, including two in the United States, issue real-time warnings.

- earthquakes--Under the National Earthquake Hazard Reduction Program (NEHRP), FEMA, National Institute for Standards and Technology (NIST), National Science Foundation (NSF), and USGS are continuing to coordinate actions to reduce the threat of earthquakes.
- landslides--USGS now provides real-time landslide hazard maps via its Internet web site (<http://landslides.usgs.gov/>). Advance warnings of major landslides are possible when the specific landslide-prone regions are properly instrumented. More general statements of the imminence of landslides are possible where the water content of the soil and the rainfall are adequately monitored.
- forest fires--The United States Department of Agriculture (USDA) and Department of the Interior (DOI) work together with other federal agencies and state and local entities to reduce the forest fire threat. Significant new resources are now available for controlled burns to reduce the fuel buildup in the United States and therefore reduce the threat of a major fire. The Fire Potential Index (FPI) is a valuable fire-management tool that was developed by USGS scientists in collaboration with scientists at the United States Forest Service (USFS). The FPI characterizes relative fire potential for forests, rangelands, and grasslands, both regionally and locally, so that land managers can develop plans for minimizing the threat from fires.
- tsunamis--NOAA has led an effort with other federal agencies (FEMA and USGS) and five Pacific states (Alaska, California, Hawaii, Oregon, and Washington) to mitigate the tsunami threat. The program provides improved tsunami warnings, hazard identification and risk assessment, and state and local mitigation planning.

- space weather--In a similar way, several federal agencies (NOAA, Air Force , NASA, and NSF) have collaborated to reduce the threat to spacecraft, electrical utilities, global telecommunications, and other sectors affected by space weather. Through x-ray imaging of the Sun, instrumenting a site between the Earth and Sun to detect solar flares, and other measures, the United States has increased warning times and reduced false alarm rates.
- watershed protection--The USDA established the Emergency Watershed Protection (EWP) program to help protect lives and property threatened by natural hazards, such as floods, hurricanes, and wildfires. It is administered by the USDA's Natural Resources Conservation Service (NRCS), which provides technical and financial assistance to preserve life and property threatened by excessive erosion and flooding. Funds are used to clear debris from clogged waterways, to restore vegetation, and to stabilize river banks, along with a new option which provides former agricultural land for floodplain easement. These easements provide permanent restoration of the natural floodplain hydrology as an alternative to traditional attempts to restore damaged levees, lands, and structures, and removes the parcel from eligibility for future federal disaster assistance. In addition, the USDA Farm Service Agency established the Flood Risk Reduction Program to provide incentives to move farming operations from frequently flooded land.
- hydrometeorological services--Through the National Weather Service (NWS) modernization and associated restructuring, NOAA has just completed a \$4 billion investment in satellites, radars, surface observing networks, and information processing to modernize NWS' ability to observe,

forecast, and warn of hydrometeorological hazards. These natural hazards constitute 85 percent of the Presidentially declared disasters and account for 67 percent of the damage suffered in the United States. As a result, the United States now experiences improved weather warnings and forecasts on time scales ranging from tornado forecasts of tens of minutes, to hurricane landfalls of a day or so, to severe winter storm forecasts out to a week or more. To improve seasonal/interannual forecasts, the United States has worked with other nations to deploy and operate a global network of buoys to monitor the ocean changes responsible for triggering El Niño, La Niña, and related seasonal to interannual changes in the patterns of severe weather worldwide. As a result, the world enjoys its earliest and best warnings to date of such events. Estimates put the savings resulting from successful anticipation of the 1997-1998 El Niño event in the \$10 billion dollar range.

- Global Disaster Information Network (GDIN). GDIN is the disaster information and decision support system of the future. It will facilitate the cooperative exchange of timely and relevant information and will be used during mitigation, preparedness, response,

and recovery phases of emergency management to save lives, reduce economic loss, and ensure the continuity of critical infrastructure. In support of GDIN, disaster information providers and user agencies, from both the public and private sectors, are collaborating to design, implement, and operate a disaster information network, first on the national level and then expanding to the international level (Figure 1-3).

Overall, federal government expenditures for pre-event mitigation, observations, and warning systems have increased at a rate of about \$100 million annually, or about 15 percent per year.

A METEOROLOGIST'S VIEWPOINT

Within the state of the science, the role of the meteorologist is to keep natural hazards from becoming natural disasters. From an operational perspective, the process (Figure 1-4) has four steps:

- Observations (in whatever form) are taken or acquired.
- From those observations, initial conditions or findings are determined, and a series of products are developed or services provided.
- Those products and services are then delivered to the customer.



Figure 1-3. Notional GDIN Home page

Natural Disaster Reduction

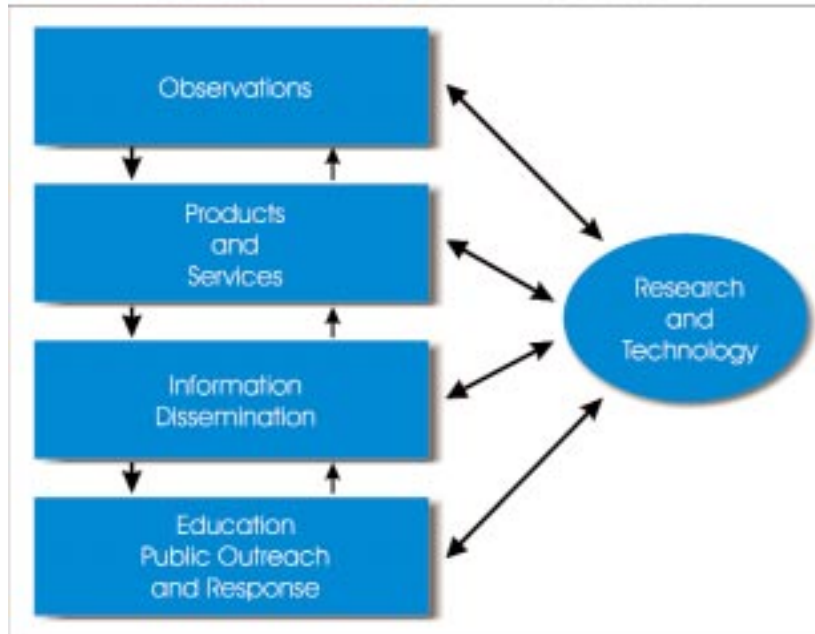


Figure 1-4. A Natural Disaster Reduction operational perspective linking observations, products/services, information dissemination, education/public outreach/response with research and technology.

Prediction's Storm Prediction Center (SPC) and the National Weather Service Forecast Office in Norman, Oklahoma (NWSFO Norman). The following is excerpted from the National Weather Service (NWS) Service Assessment, *Oklahoma/Southern Kansas Tornado Outbreak of May 3, 1999*, August 1999.

Observations

The observational analysis provided the initial indication that many elements of a classical Great Plains severe weather outbreak were in place during the afternoon and evening of May 3, 1999. The synoptic-scale pattern was characterized by a large-scale middle and upper tropospheric trough over the western United States and a downstream ridge to the east (Figure 1-5). There was a strong upper-level jet stream on the west side of the trough, and moving through the synoptic-scale trough were several

- The customer then reacts or does "something" as a result of receiving the product or service.

Ideally, there is feedback throughout the process so that the meteorologist can respond to deficiencies at any step in the process. More or different observations or faster and more reliable communications may be needed. The criteria for forecast advisory and warning products may need to be adjusted, or we may need to better understand how and why a customer responds or chooses not to respond. At the same time, we must tighten the linkages with the research and technology communities to ensure that their efforts are focused on addressing the deficiencies identified within the operational process.

The Oklahoma City tornado outbreak of May 3, 1999, provides an outstanding case study of the natural disaster reduction operational process in action. The key players are the National Centers for Environmental

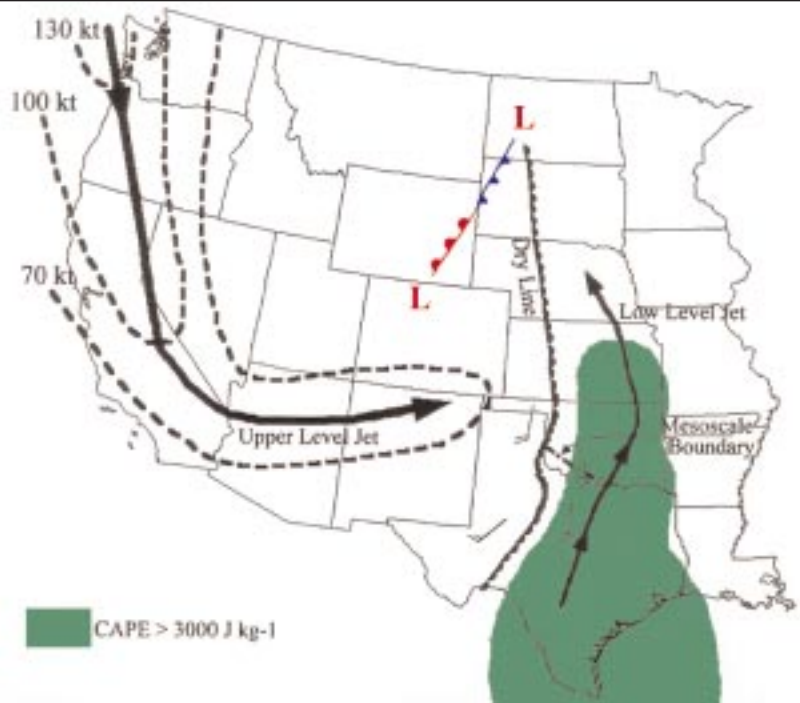


Figure 1-5. Significant features associated with the May 3, 1999, tornado outbreak. Depicted are the 4 p.m. CDT positions of the upper-level and low-level jets, dryline, surface winds, and a mesoscale boundary in southwest Oklahoma. Shaded area is where the Convective Available Potential Energy (CAPE) exceeded 3000 Joules kg^{-1} .

(Source: NWS Service Assessment, *Oklahoma/Southern Kansas Tornado Outbreak of May 3, 1999*, August 1997)

smaller scale short waves, the most important of which was located along the New Mexico/Texas border by late afternoon. At the surface, a low pressure center was located along the Wyoming/Colorado border, and a low pressure trough extended southward along the lee of the Rockies. In response to the approaching jet stream and short wave, several atmospheric adjustments took place over the Plains. The surface low and lee trough deepened throughout the afternoon. This caused surface winds ahead of the dryline to strengthen and a strong low-level, southerly jet stream developed from northwest Texas into Oklahoma, allowing deep low-level moisture to stream northward into Oklahoma and Kansas. As surface heating proceeded through the afternoon, mixing of the shallow moisture over southwest Texas moved the dryline to near the western Oklahoma border. At the same time, the lapse rates in the mid-troposphere over Kansas and Oklahoma were steepening, owing to the effects of the approaching short wave. These factors contributed to the development of the large atmospheric instability and an approaching upper-level jet produced vertical wind shear profiles favorable for the development of supercell thunderstorms.

With an atmosphere conducive to the development of supercell thunderstorms, the last element necessary was a triggering mechanism. By late afternoon, two bulges developed along the dryline--one located southwest of Wichita Falls, Texas, and a second near Woodward, Oklahoma. In addition, a pool of cooler, drier air over central Oklahoma resulted in a mesoscale boundary which was oriented from southwest Oklahoma to south-central Oklahoma, separating the cooler air from the very warm, moist air which was streaming northward across western Oklahoma. The presence of the dryline bulges and the mesoscale boundary led to prolonged enhanced moisture convergence which resulted



Figure 1-6. F3 tornado located 7 miles south of Anadarko, Oklahoma on May 3, 1999.

(Source: NSSL photograph by D.Zaras)

in explosive thunderstorm development over southwest Oklahoma by late afternoon and northwest Oklahoma to south-central Kansas by early evening (Figure 1-6).

Products and Services

The potential for severe weather was reflected in NWS forecast products as early as 36 hours prior to the outbreak. On May 2, the SPC's Day 2 Severe Weather Outlook (SWO) (valid May 3) predicted a slight risk for severe weather. At 6:30 a.m. on May 3, NWSFO Norman issued a Thunderstorm Outlook, noting a slight risk of severe storms in western and central Oklahoma that afternoon and night. It mentioned the increasing low-level moisture, dryline, and an approaching upper-level low pressure would combine to cause a threat of hail, damaging winds, and isolated tornadoes. It also cautioned emergency managers and spotter groups to be prepared for possible activation in the afternoon.

At 11:15 a.m., May 3, 1999, the SPC's Day 1 SWO was upgraded to a moderate risk for severe thunderstorms in the Oklahoma/Kansas outbreak area based on the 7 a.m. upper-air soundings, mid-day wind profiler observations and the Rapid Update Cycle II (RUC II) forecasts of instability and shear. From

mid-morning to mid-afternoon on May 3, the vertical wind profiles from the profiler at Tucumcari, New Mexico, showed a descending and strengthening jet approaching Oklahoma. The jet was deeper, stronger, and lower in the atmosphere than the forecasts from the numerical models and favored development of supercells. It was the profiler data that led SPC forecasters to upgrade the SWO from moderate to high risk for severe weather in the outbreak area and caused F2 or stronger tornadoes to be highlighted in the Experimental Probabilistic Outlook. In the opinion of the NWS Service Assessment Team, without the wind profiler data, SPC forecasters would not have upgraded from moderate to high risk. Also the state of readiness of NWS offices, emergency managers, and the media in the severe weather outbreak area would not have been as high.

The SPC issued a Tornado Watch for western and central Oklahoma, including Oklahoma City, at 4:30 p.m., valid 4:45 p.m. to 10 p.m. The first Severe Thunderstorm Warning was issued by NWSFO Norman at 4:15 p.m. Based on Weather Surveillance Radar-1988 Doppler (WSR-88D) radar signatures, the first Tornado Warning followed at 4:47 p.m. About 10 hours later, after the main part of the event concluded, NWSFO Norman had issued 70 tornado warnings and 46 severe thunderstorm warnings for 32 of the 56 counties within its county warning area (CWA).

NWSFO Norman was very successful in giving the public significant advance warning of the individual tornadoes. They achieved a remarkable 32-minute lead-time average for the first tornado warning issued in each of the Oklahoma City metropolitan area counties that was affected by the F5 tornado. Warnings for the Oklahoma City F5 tornado, which hit Grady, McClain, Cleveland, and Oklahoma Counties, were issued with lead times of 65, 18, 31, and 13 minutes, respectively.

In addition to its excellent warning support, NWSFO Norman kept the pub-

...TORNADO EMERGENCY IN SOUTH OKLAHOMA CITY METRO AREA...

AT 6:57 P.M. CDT...A LARGE TORNADO WAS MOVING ALONG INTERSTATE 44 WEST OF NEWCASTLE. ON ITS PRESENT PATH...THIS LARGE DAMAGING TORNADO WILL ENTER SOUTHWEST SECTIONS OF THE OKLAHOMA METRO AREA BETWEEN 715 P.M. AND 730 P.M. PERSONS IN MOORE AND SOUTH OKLAHOMA CITY SHOULD TAKE IMMEDIATE TORNADO PRECAUTIONS!

THIS IS AN EXTREMELY DANGEROUS AND LIFE THREATENING SITUATION.

lic informed with numerous Severe Weather Statements (SVS), Short Term Forecasts (NOW), and Local Storm Reports (LSR). During the most active period of this event (4 p.m. until midnight), 48 concise SVSs, 9 NOWs, and 14 LSRs were issued.

To heighten awareness of the severity of the situation, NWSFO Norman alarmed several SVSs on the NOAA Weather Radio (NWR) and issued an effective SVS at 6:57 p.m. that included the words "TORNADO EMERGENCY" in the headline.

The excellent lead times and overall support provided by NWSFO Norman can be attributed to several factors. These included very good severe weather knowledge and radar interpretation skills; modernized NWS equipment, especially the WSR-88D and the Advanced Weather Interactive Processing System (AWIPS); a well-trained and widespread spotter network; and the long-lived nature of several of the tornadoes.

Information Dissemination

All NWS warnings, forecasts, and statements were disseminated via the NOAA Weather Wire Service (NWWS), NOAA Weather Radio (NWR), the Family of Services (FOS), the Emergency Alert System (EAS), the National Warning System (NAWAS), the local amateur radio network, and the Emergency Managers

Weather Information Network (EMWIN). NWS information was also disseminated by local television and radio stations, as well as through the Internet and OK-FIRST (Oklahoma's First-response Information Resource System using Telecommunications).

Local radio stations indicated that NOAA Weather Radio information was very helpful in their efforts to alert the public, and emergency managers were pleased with the severe weather information supplied by the various NWS dissemination systems. The Deputy Director of the Oklahoma Civil Emergency Management Agency stated that EMWIN provided prompt information to the emergency managers during the event and that EMWIN is one of the most valuable emergency management tools to come along in many years. The Oklahoma Climatological Survey's OK-FIRST was also cited by local emergency managers as a very valuable tool during the outbreak. The OK-FIRST system provides Internet access to real-time WSR-88D radar data plus all NWS text products.

In addition, NWSFO Norman's strong partnership with the amateur radio community in central and western Oklahoma proved to be very valuable during the outbreak. Amateur radio information played a crucial role in the warning process and in provid-

ing subsequent follow-up information (SVSs and LSRs); 75 severe event reports were received via the amateur radio network. The forecast office's amateur radios also provided an important backup capability during periods when the phone service was interrupted.

Education, Public Outreach, and Response

The fact that casualties were low (compared to the many thousands that were affected by the main Oklahoma City tornado) is, in large part, attributable to the effective response of the public to early NWS severe weather warnings. To help enhance public response, NWSFO Norman has conducted an aggressive preparedness campaign for years in Oklahoma. Within the 3 months prior to the outbreak, 32 spotter training classes were held. In the 5-month period leading up to the outbreak, the office hosted nine tours, conducted four safety presentations, participated in three televised safety shows, and presented two safety displays (information booths) within its CWA. NWSFO Norman has also been active in Oklahoma's annual severe weather awareness week.

The Oklahoma City radio and television stations also played a crucial role in the effective public response. They rapidly communicated NWS warnings, gave hours of live coverage of spotter reports, and provided aerial and ground-level video of the tornadoes. Using the cable television override capability, the Moore city emergency manager broadcast NWS warnings (audio only) to the community. Many radio stations provided simulcasts of the live telecasts from the three primary television stations as the main tornado approached the Oklahoma City metropolitan area.

The effective public response saved lives. In one instance, a Grady County resident living in an area with primarily mobile homes credited the advance NWSFO Norman warnings with saving many lives in his neighborhood.

The early warning gave his family time to gather neighbors into his storm cellar. Thirty-five people crammed into the cellar. The winds of the F5 tornado pulled the cellar door open, but all survived. Their mobile homes were destroyed.

In another instance, a large Oklahoma City area telecommunications company called NWSFO Norman after the tornado to express thanks for their assistance in updating the company's severe weather safety plan, completed prior to the tornado. The new plan instructed employees not to travel home during a tornado for safety reasons. This was a significant change from the previous plan, which had allowed employees to go home. The new plan may have saved lives since the F5 tornado passed within



Figure 1-7. Vehicle resting against tree in Moore, Oklahoma, approximately 1/2 mile southwest of the Shields Boulevard exit on Interstate 35.

(Source: NWS Photo by K. James)

1 mile of the company.

Research and Technology

While technology was an important key to NWSFO Norman's success, the use of that technology also highlighted the need for future improvements. NOAA's National Severe Storms Laboratory (NSSL) developed the Warning Decision Support System (WDSS), which provided useful infor-

mation to the warning staff at NWSFO Norman during the outbreak. WDSS offers access to a full wide-band suite of radar reflectivity and velocity data, improved algorithm guidance, and dynamic tables which rank storms according to algorithm-derived severe weather threats. The WDSS severe storm cell tables and trend displays focused the forecasters' attention on those storms that could require warning, and WDSS displays of full resolution velocity products were confidence builders for tornado warning decisions. WDSS also incorporates advanced versions of the NSSL mesocyclone detection and tornado detection algorithms. To fully complete the transition of this technology into operations, however, two upgrade projects are needed. The NEXRAD Open systems Radar Product Generator (ORPG) is required to implement the advanced algorithms and to provide high resolution products to AWIPS, and the NEXRAD Open systems Radar Data Acquisition (ORDA) project will provide improved base data (e.g., high resolution reflectivity and better anomalous propagation suppression).

AWIPS was also a success story. Without AWIPS, it would have been impossible to duplicate the number of successful warnings and lead times and to keep track of the large number of severe storms. During the months prior to the event, the NWSFO Norman staff invested substantial effort customizing preformats for warnings and SVSs within the AWIPS WarnGen module, to include the generation of detailed city boundary backgrounds, which obviously paid big dividends during the outbreak. AWIPS, however, has shortfalls which can only be remedied through research and technology upgrades. AWIPS pixel replication zoom distortion led fore-

casters to supplement WSR-88D velocity data with alternate display systems, e.g., WDSS. Improvements in the rapid display of non-distorted magnified WSR-88D products should be a top priority. Also, NWSFO Norman accessed, via the Internet, data sets not available through AWIPS, which helped forecasters focus on the convective initiation over southwest Oklahoma. One solution would be to develop the methods/technology for ingesting data sets into AWIPS via the Local Data Acquisition and Dissemination (LDAD) system.

SUMMARY AND CONCLUSION

The decade of the 1990's has seen a dramatic change in the way the United States responds to natural hazards. There has been a major shift in policy toward increasing pre-event efforts through programs like Project Impact, improved information dissemination systems, and public outreach and education programs to mitigate the impacts of natural hazards rather than relying on emergency response and reconstruction alone. The United States has also capitalized on research and technology developments to significantly improve its ability to observe, forecast, and provide timely warnings of impending natural hazards.

In the case of the May 3, 1999, tornado outbreak, a natural disaster was not prevented, but with an effective plan of action, the players were able to positively shape the outcome. The actions of the National Weather Service, in partnership with state/local emergency managers, local radio and television stations, and amateur radio operators, evoked an effective and timely public response, which significantly reduced the impact of this devastating natural hazard. The bottom